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NOTES ON OBSERVING THE ZODIACAL LIGHT.

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The zodiacal light can not be well seen unless it is nearly perpendicular to the horizon, and then it appears as a tapering cone of light which passes near and far beyond the zenith; and as the axis or central line of this light closely follows the ecliptic, this condition requires observations to be made in low latitudes, within or nearly within the tropics; and even then the conditions for the Northern Hemisphere are best satisfied in February, March, and April for the eastern branch, and in August, September, and October for the western branch, seen in the evening and morning, respectively.

The positions of these branches should be considered with respect to the sun at noon; the western branch sets before the sun so that the eastern branch is seen an hour or so after sunset, and the western branch is seen an hour or so before the following sunrise. And as after some practice the light may be seen across the whole sky, it is necessary to note on which branch observation is made.

When the zodiacal light is seen at its best its illumination is equal to that of the first or last rays of twilight; its breadth at the horizon about 21° from the sun is about 32° ; and its breadth and illumination gradually decrease as the distance from the sun along the axis increases. Where the two branches meet opposite to the sun there is a considerable increase in the light, and the band there is broader; this appearance is known as "the counterglow," and it may easily be seen high up in the midnight sky when it may be very difficult to follow the branches.

Now, unless the zodiacal light is fairly perpendicular to the horizon, as already said, its light mingles with the diffused light almost always seen along the horizon at night, and then its figure becomes greatly distorted and its breadth may apparently become as large as 60° or 70° ; but the less diffused light there is the smaller the breadth, until the limit of 32° is reached. Beginners are therefore advised to observe 20° or 30° above the horizon, where the figure of the zodiacal light will be seen to be perfectly uniform.

On any clear dark night, in the absence of moonlight and all artificial light, the observer should remain some time in the open air and allow his eyesight to become sensitive, so that he can easily follow the light along the ecliptic; and he will be surprised to find after 10 or 15 minutes how much wider it becomes and how much farther it extends, until at last the counterglow is reached; indeed, instead of instrumental means, he requires a level terrace to walk on, a wide expanse of sky, and aptitude to admire the whole tropical scene.

The next thing is to select a part of the light for measurement of its breadth; the Milky Way, or bright planets, may interfere, and all such disturbing causes should be avoided. Then the right-hand boundary of the light may be seen to pass over a known star or between two known stars, so that a point can afterward be made on a star-map marking its position; and similarly for the left-hand boundary. It is not essential that the line joining the two points should be exactly at right angles to the axis, but it should be nearly so. A pencil note should then be made of the conclusions arrived at with respect to the points marking the boundaries; and if much artificial light is required time must again be allowed so that the eye may become sensitive again to make another observation at another part.

The following day the observations should be reduced; the points on the boundaries should be marked in pencil on a star-map and joined by a straight line; the middle

point of this line marks a certain point on the central axis; and the latitude and longitude of this point and the breadth of the light at this point can easily be found with a pair of dividers. The sun's longitude must be taken from a nautical almanac; and then the distance of the point on the central axis from the sun will be the longitude of the former minus the longitude of the latter, if the observation be made on the eastern branch; if the observation be made on the western branch it will be the longitude of the latter minus the longitude of the former.

From a series of observations a table can be drawn up showing the breadth of the light and its geocentric latitude at different angular distances from the sun, which leads to important results; but there are certain months when observations made of the latitude of certain parts of the zodiacal light are very valuable; these are the counterglow in April and October, and points 90° from the sun on both branches in January and July.

And now very simple geometrical considerations will lead the observer to conclude that he is dealing with a most interesting part of the solar system, important as every part of the solar system must be, and requiring every possible care and accuracy of observation.

In former articles the author has shown that the zodiacal light does not actually coincide with the plane of the ecliptic, but is inclined to it at an angle of $1^{\circ} 45'$, the ascending node being at longitude $105^{\circ} 30'$, so that it really coincides with the invariable plane. It was surmised that the zodiacal light was caused by the reflected light of the sun on the remaining meteoric matter after the formation of the solar system; and later it was shown that the density of this matter varies inversely as the square of the distance from the sun and inversely as the distance from the medial plane. What has been done, however, only opens fresh fields for investigation.

SHOOTING STARS REVEAL A HIGHER ATMOSPHERE.

An elaborate memoir by Prof. G. von Niessl, formerly of Brunn, now of Vienna, was lately published in the *Encyklopädie der Mathematischen Wissenschaften*, Band VI, in which he examines the highest altitudes at which meteors or shooting stars become visible. From these altitudes, of course, we conclude that the atmosphere must extend still higher above the earth, since the meteors must have pursued a considerable distance before, by compressing and heating the thin air, they could have thereby acquired a temperature high enough to become visible. The exact determination of the altitudes and motions of these meteors has hitherto required so much time on the part of observers and computers that comparatively few astronomers have devoted themselves to this work. But the study is of more importance to meteorology than to astronomy, and a simple photographic apparatus must be devised that will make it practicable to easily collect the exact data that will facilitate the calculation of the altitude and velocity of any shooting star, meteor, or bolide that may be recorded. But these "shooters" give us not merely their own heights and the chemical constituents of special regions of the atmosphere, they do much better; many of them produce great noises that are heard at the earth's surface and are likened to thunder or the discharge of cannon. From the records of such noises we should learn much about the differences of density in the layers of atmosphere and much about the atmospheric movements that are then prevalent at altitudes far beyond the reach of ordinary balloons. We know that our atmosphere is held by gravity to the earth and that both are revolving rap-

idly around our polar axis, but this idea must be extended so as to include regions that are far higher than has hitherto been assumed. Our atmosphere is not merely that region in which clouds and rains occur; it is not merely a troposphere within which the highest cirrus clouds are seen; it is not merely a stratosphere within which there are but slight vertical temperature changes going on and one that is accessible to our highest sounding balloons; it is not merely a high layer of air within which the aurora occurs; it includes the region within which shooting stars become first visible and which may be the frontier or boundary of the earth considered as a planet. It may be doubted whether there is a definite boundary to our atmosphere; probably our lower air merges imperceptibly into an interplanetary space within which other planets, the zodiacal dust ring, and various gases are free to move according to the laws of universal gravitation, centrifugal force, and inertia. This material region in space binds our whole planetary system together as a unit. The gases, the atoms, the electrons, the corpuscles of Sir J. J. Thomson—all the obscure electrical, molecular, and atomic phenomena, so far as known—seem to belong to both the sun, the planets, and the attendant space. We are forced to this train of thought whenever we collate the observations of any great meteor, such as that of Christmas Eve, 1873, or that of February 18, 1912.¹

¹ The latter meteor was studied by Cuno Hoffmeister, of Sonneberg, Saxe-Meiningen, whose results are published on pages 32-46 of "Mitteilungen von der Freunden der Astronomie und Kosmische Physik," April, 1912, 22, Heft 3.

The importance of the study of bolides, shooting stars, and small meteors led the Astronomical Society of Antwerp (Anvers) to establish an international scientific organization (the Bureau Central Météorique), whose founder and first president was Carl Birkenstock of Hamburg, and whose secretary is Dr. Cuno Hoffmeister of Sonneberg, Saxe-Meiningen. (See *Minerva*, 1913-14, p. 582.)

Sonneberg is in latitude $50^{\circ} 20'$ north and longitude $11^{\circ} 10'$ east of Greenwich; Jena is in latitude $50^{\circ} 55'$ north and longitude $11^{\circ} 35'$ east of Greenwich; hence Jena is about 44 miles distant from Sonneberg, bearing north 30° east. According to the *Vierteljahrschrift* of the German Astronomical Society for 1914, page 49, Dr. Nagel of Baku, at present observer at Jena Observatory, by an arrangement with Dr. Cuno Hoffmeister of Sonneberg, has maintained simultaneous observations of meteors during the several star showers of 1913 and will maintain them during 1914, if nothing prevents. The meteors of these star showers are small compared with the bright bolides that occasionally occur, but every form of meteor has its value in the study of the upper atmosphere. So long as such meteors are invisible they may be considered as astronomical bodies belonging to the solar system, but when they become visible by reason of their compression of the upper atmosphere they become an integral part of the earth considered as a planet, consisting of an agglomeration of solids, liquids, and gases.